The Biennial International Conference on Experimental Solid Mechanics (X-Mech 2016)
16-17 Feb., 2016, Tehran, Iran

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Center of Excellence in Experimental Solid Mechanics and Dynamics,
School of Mechanical Engineering, Iran University of Science and Technology

An experimental study on the effect of buckling initiators on energy absorption behavior of thin-walled steel cones

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***Abstract*- Thin-walled structures are used widely in engineering and industry. High strength and stiffness, low cost, very high loading capability and high energy absorbing capability are some of their advantages. When a thin-walled structure is subjected to axial loading, it deforms consecutively under different mode shapes and acts as a very good energy absorber. Although, thin-walled structures have so many above mentioned advantages as energy absorbers, when they are subjected to axial loading, they usually have an intense initial peak force. This initial peak force is dangerous and may cause serious harm or injury to the structure or people. To reduce this initial peak load some proper methods are developed such as creation of grooves, dents, cut out or any imperfection on proper location of structure, using corrugated structures and etc. Although these methods reduce initial peak force, they reduce the stiffness of structures under the actual loading conditions. Therefore a thin-walled specimen that its energy absorbing capability does not reduce under actual working conditions is highly required. In this paper a special buckling initiator is used to reduce the initial peak force of thin-walled steel conical specimens under axial loading. The buckling initiators are steel strips that are attached horizontally at one end of specimens using brazing. The geometry of Initiators is similar to a simple strip or two strips that are installed over each other similar to a plus (+) pattern. The axial loading is applied by two steps. In the first step, load is applied to initiators and pull the strips towards another end of cone. Therefore edge of cone that is attached to strips, is deformed plastically and thus initial stiffness of cone is diminished and also peak force is reduced. In the second step, loading is applied by a thick steel plate to the end of the cone continuously. The experimental results show that by using the buckling initiator, the large progressive deformation is carried out under different shape modes and act as a very good energy absorber.**

Keywords - Experimental Mechanics, Buckling Initiator, Energy absorption, Thin-walled structures

I. INTRODUCTION

Energy absorbing devices are employed in vehicles to lessen the potential danger of impact accidents. Lu and Yu [1] published a monograph which introduces fundamental topics pertaining to energy absorbers. It was outlined that energy absorbing devices usually include the following features: (1) controlled and constant reactive force, (2) long stroke, (3) stable and repeatable deformation mode, (4) light weight and high specific energy absorption capacity, and (5) low cost and easy installation.

The major class of energy absorbing components are thin walled tubes that amongst them, steel thin walled cones are well known because of their low cost, good efficiency, excellent ductility and ease of manufacturing. Thus, Mamalis et al [2] derived and presented the analytical expressions describing the load-deflection curve during the deformation process for conical thin walled shells. Johnson and Reid [3] also provided an extensive review of metallic energy dissipating systems and devoted one section to the plastic deformation of tubes, conical shells and spherical shells. The experimental deformation and load–displacement curves of tubes were affected by several other factors, including the folding parameter (ratio of internal folding to fold length) [4], load eccentricities [5], foam-filling [6–9], cut-off and grooving on the tube wall [10–15], and any disturbances in the periodicity of folding. Investigations carried out on designing frusta tubes as collapsible shock absorbers show that almost no work has been reported on development of a new method for controlling the axial crushing. On the other hand, in all earlier studies for axial crushing of frusta tubes, it has been observed that the height of the first peak (maximum crushing load), which is associated with the first hinge in the load–displacement curves was much bigger than the other peaks.

In this article, an experimental analysis has been developed for axial crushing of steel thin walled cones with different patterns of steel strips on their open top to specify the best qualified pattern for the features mentioned.

II. EXPERIMENTAL TEST PROCEDURE

The conical tubes were fabricated from steel plates using a spinning process. The circular coupons were cut from steel plates of a thickness of 1.1 mm and stretched over the surface of a rotating die. The thickness of the end of the tubes is the same as the coupons' thickness, while there is some thickness gradient observed in the tubes' walls due to stretching of the coupons over the die surface. Also, Quasi-static loading tests were carried out by a Zwick/Roel Amsler HB100 machine in fatigue laboratory of Ferdowsi university of Mashhad.

Figs (1-10) show the driving Load-Displacement curves, i.e. L-D curves obtained from the tests and the photo taken from the specimens before and after the tests.

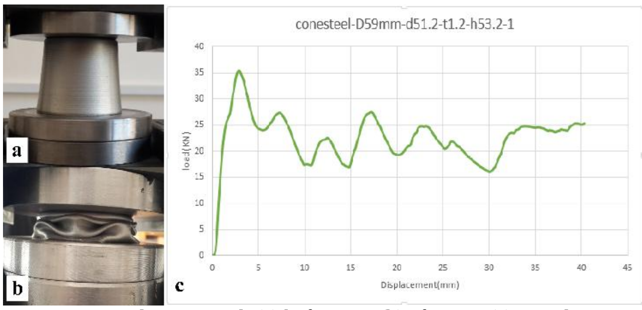

Fig 1: simple cone steel, (a) before test (b) after test (c) L-D diagram

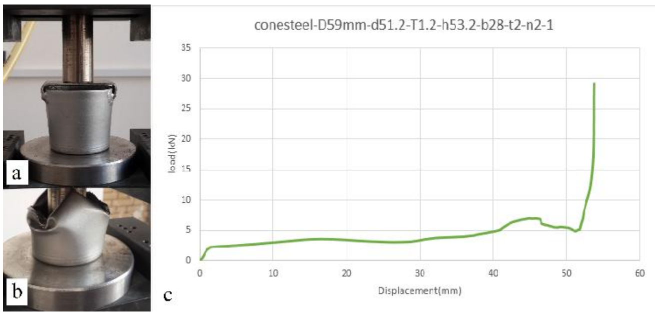

Fig 2: cone steel with one strip, (a) before test (b) after test (c) L-D diagram

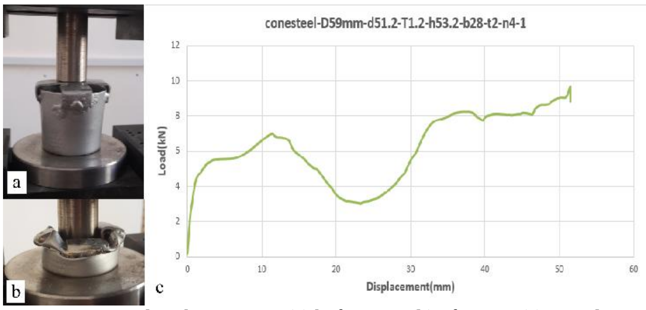

Fig 3: cone steel with two strip, (a) before test (b) after test (c) L-D diagram

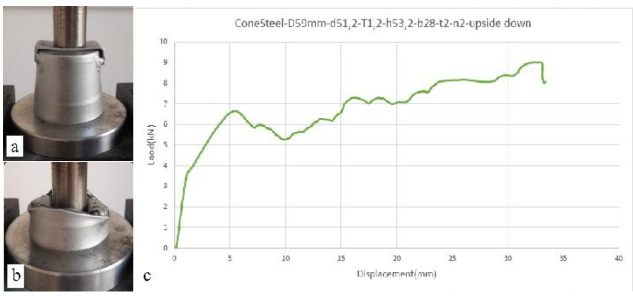

Fig 4: upside down cone steel with one strip, (a) before test (b) after test (c) L-D diagram

III. CONCLUSION

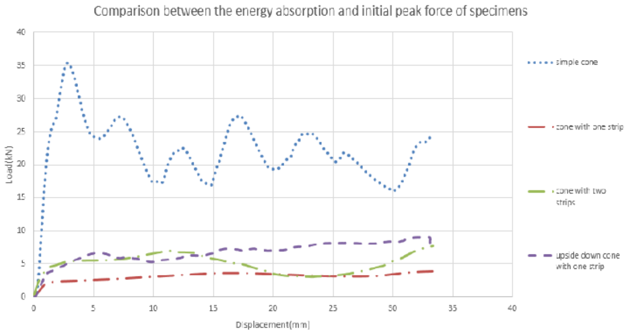

Fig 5: comparison between the energy absorption and initial peak load of specimens

As it is observed from the above diagram the initial peak load for the simple cone is much higher than others as well as the energy absorption which is the area under the L-D curve. Amongst specimen with initiators the one with two strips is the most efficient one for the purpose of the study.

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